GRAIN FUMIGATION & SEED TREATMENT TRAINING MANUAL

STATE OF MONTANA
DEPARTMENT OF AGRICULTURE
HELENA, MONTANA
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PREFACE

This manual was prepared as a study guide for all commercial applicators engaged in seed treatment and fumigation of stored grain. It includes information on recognition of common stored grain pests and important seed pathogens, management of grain pests, chemical control (including fumigants and seed treatments) of grain pests, application equipment, and safety considerations when using these chemicals. The manual may be used as a study aid for the seed treatment test, which includes sections on fumigation and stored grain pests.

To simplify information, trade name products and equipment have been mentioned. No endorsement is intended, nor is criticism implied of similar products or equipment which are not mentioned.

We wish to acknowledge the help of the personnel of the Environmental Management Division, Montana Department of Agriculture, in preparing this manual.

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CHAPTER 1

RECOGNITION OF COMMON STORED GRAIN INSECT PESTS

A. Introduction

It has been estimated that loses of grain in storage due to insects often equals or exceeds losses incurred in the field. Losses extend beyond that grain directly consumed by the pests. Frass, cast skins, broken kernels, webbing and other debris may render the grain unfit for human consumption. In addition, heating of the grain caused by an insect infestation and the resulting "sweating" provide an ideal environment for the introduction of storage molds, further reducing the value of the grain. World wide losses to stored grain insect pests have been estimated at 5 to 10 percent. Losses exceeding 50% are not common in tropical environments. Storage losses in the United States alone may exceed $600 million annually.

Prevention of an insect infestation in stored grain must be a primary consideration beginning with its initial storage on the farm. Economically speaking, insects and storage molds greatly affect the quality and market value of grain. Even a seemingly minor infestation at the farm level can rapidly develop into damaging populations in subsequent transport and storage in the market place. It is essential that farm stored grain be kept free of insect pests to insure its acceptance in the domestic and foreign market.

Cold Montana winters do not prevent buildup of stored grain insect pests in storage facilities. Thirty or more insect species may be found infesting stored grain in the northwest, however, seldom do more than five or six species reach economic levels in Montana. This chapter will help the producer storing grain on the farm and the commercial elevator operator recognize the more common stored grain pests and become familiar with the available methods of managing them.

B. Classification of Stored Grain Insects

Stored product insect pests may be arbitrarily divided on the basis of their feeding habits, into two categories: Primary invaders are those pests capable of attacking and infesting sound whole grain. Secondary invaders, unable to penetrate sound kernels, are restricted to feeding on broken kernels, debris, and grain defiled by the infestation of primary invaders. (Figure 1) While the secondary invaders are generally unable to initiate an infestation, they will contribute greatly to grain spoilage once they become established.

Figure 1. A. Primary invader (granary weevil) can infest whole grain. B. Secondary invader (Indian Meal Moth) can feed only on broken grain kernels and debris.

Stored grain insects are predominantly beetles (Order Coleoptera) and moths (Order Lepidoptera), although representatives of seven other orders have been found occasionally in stored products. Insects in these two major groups develop by complete metamorphosis. As illustrated below, (Figure 2), this involves development from the egg to a worm-like or caterpillar-like larva, followed by the pupa or resting stage and finally the adult. Knowledge of these life forms is important since both the larvae and adults of the beetles and only the larvae of the moths are damaging to the grain. While beetle pests are quite common, only a few moth species are able to overwinter in Montana and these are most troublesome in heated mills or elevators.

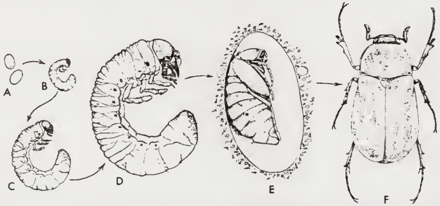


Figure 2. Example of complete metamorphosis in the May beetle. A. eggs, B. C. D. three larval instars E. pupa F. Adult.

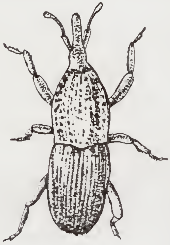
While it is wise to have a positive identification made of each pest by a specialist prior to treatment, with a little experience, a useful guide and a 10X or 20X magnifier, it is possible for the layman to recognize the more common stored grain insect pests. The following descriptions will be helpful in

recognizing the principle stored grain insects encountered in Montana.

C. Representative Stored Grain Insects

Granary Weevil (Sitophilus granarius)

The granary weevil and the very similar rice weevil (S. oryzae) are the two most important weevils attacking stored grain in the United States. The adults of both species can be readily recognized by their long, slender snout.



Granary Weevil
Stiophilus granarius

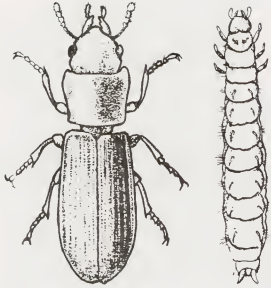
The granary weevil is not more than 3/16 of an inch long and varies in color from medium brown to black. The thorax possesses elongate depressions and there are no wings under the wing covers. The rice weevil is seldom longer than 1/8 inch, varies in color from reddish brown to black and can be distinguished from the granary weevil by having round punctures on the thorax and a fully developed pair of wings.

Although field infestation of these weevils do not occur in Montana, both are encountered in stored in stored grain as primary invaders. Damage is done by both the adult and the larva. The female bores a small hole in the grain kernel into which she lays an egg. The cell is sealed and the egg hatches into a small legless white grub which continues to feed within the kernel until pupation. The adult emerges shortly thereafter. The female is capable of laying from 50 to 250 eggs in the manner. Development under warm conditions takes about four weeks but this period becomes quite extended in areas of cold winter conditions.

Cadelle (Tenebroides mauritanicus)

This elongate blackish beetle is up to 1/2 inch in length and is among the largest insects attacking stored products. The Cadelle is recognized by its size and the narrow waist separating the thorax and the abdomen.

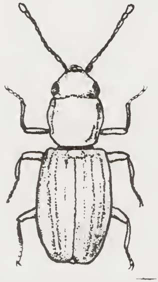
The larva of the Cadelle is also quite large (up to 3/4 inch) and can be recognized by the dark head, the black spots on the top of the first three body segments, and the black hooks at the tip of the abdomen. Females are capable of laying up to 1,000 eggs in clusters among debris and food materials. Larvae complete their development in two to fourteen months. They pupate in a secluded spot, often boring into the timbers of the bin. More commonly found infesting flour, these beetles will also attack grain, going from kernel to kernel devouring only the germ. Both larvae and adults can live for some time without food and may remain hidden among debris or in cracks and crevices after the grain has



been removed from the bin. Unless control measures are taken, infestation of new grain placed into the bin will occur rapidly.

The Cadelle is one of the longest lived of the stored grain insects, some living up to two years.

Cadelle or Flour Worm
Tenebroides maritanicus



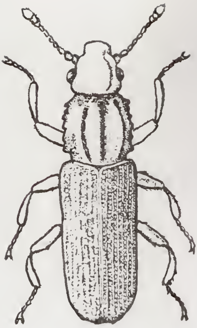
Rusty and Flat Grain Beetles
(*Cryptolestes spp.*)

Rusty Grain Beetle, Flat Grain Beetle (*Cryptolestes ferrugineus, C. Pusillus*) These two beetles and a closely related species, *C. turcicus*, among the smallest and most common insects found infesting stored grain. The three species are very similar in appearance and can be distinguished only by the length of the male's antennae. Eggs are laid in crevices or debris. The larvae are found on wheat germ and often damage only this part of the kernel.

These beetles are normally secondary invaders. However, there is some evidence to suggest that they are capable of a primary role of a primary role on occasion.

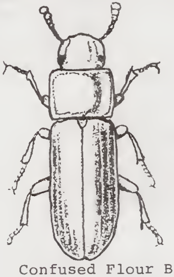
Saw Toothed Grain Beetle (*Oryzaephilus surinamensis*) These reddish brown beetles about 1/10 inch in length are recognized by the distinctive saw-toothed notches on either side of the thorax. This insect is cosmopolitan in distribution and a common invader of all stored vegetable products, especially stored grain.

The female will scatter from 43 to 285 eggs loosely among foodstuffs. The emerging larvae do not live within one kernel but actively crawl about from kernel to kernel. Development from egg to adult may take place in three to four weeks in summer. This beetle is often associated with the granary weevil.

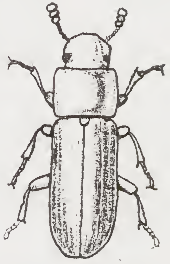


Saw Toothed Grain Beetle
(<u>Oryzaephilus</u> <u>surinamensis</u>)

<u>Confused Flour Beetle and Red Flour Beetle(Tribolum confusm, T. castaneum)</u> These two species are secondary invaders found in all types of storage facilities and are associated with many different products. They are often found together infesting broken damaged grain. Although the adults are quite similar, they may be distinguished by the structure of their antennae. Only the last three antennal segments are enlarged in the red flour beetle whereas all segments are gradually tapered towards the tip in the confused flour beetle.

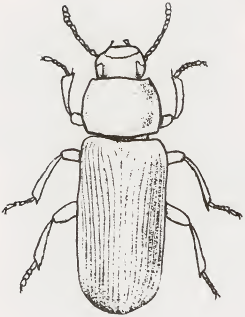


Confused Flour Beetle
<u>(Tribolum confusum)</u>



Red Flour Beetle
<u>(T. castaneum)</u>

Females may lay up to 500 eggs. The larvae feed up to four months before pupating. A complete life cycle will require three to four months under ideal conditions.

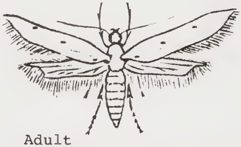


Mealworm
(Tenebrio spp.)

Mealworms (Tenebrio spp.)
The larvae of these beetles are large (up to an inch in length) and resemble wireworms in appearance. They are shiny, hardbodied, and yellow to brownish in color. The adults are also large in size (up to _ inch) and are black in color. Unable to infest whole grain, mealworms breed in refuse and broken grain and prefer moist conditions. There is one generation per year.

Flour Grain Moths
(several genera)

The larvae of several moth species sometimes become pests of stored grain and feed as secondary invaders. The Angoumois Grain Moth (Sitroga cerealella) is probably the most destructive species found in western states. The adult is a small, pale golden moth with narrow fringed wings. The caterpillars are short and dumpy with faintly developed prolegs on the abdomen.



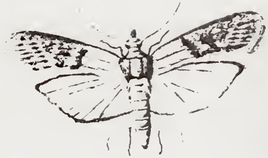
Adult

Larva inside grain kernel

Angoumois grain moth (Sitotroga cerealella)

The adults attack grain in the field. The larvae feed within the kernels and are transported to storage. Modern harvesting methods and machinery have greatly reduced damage by these species.

The Indian meal moth (Plodia interpunctella) and the similar warehouse moth (Ephestia elutella) are examples of secondary moth pests living mainly as scavengers on broken grain, flour, and many other types of dry vegetable products.



Adult | Indian meal moth (Plodia interpunctella) | Larva

The female Indian meal moth will lay between 60 and 300 eggs either singly or in groups on top the grain mass. The emerging larvae are usually yellowish-white but may sometimes appear redish or greenish. When mature, the larvae may be 3/4" in length. Larvae are active spinners and will cover the grain mass and sides of the elevator with webbing. Pupation occurs in a cocoon. The life cycle may be completed in as little as 3-4 weeks in warm climates or as long as 2-6 months in northern climates.

CHAPTER II

MANAGEMENT OF STORED GRAIN INSECTS

A. Ecology of Stored Grain Insect Buildup

A suitable food source and proper environmental conditions are critical factors required to support a population of any store grain insect. The grain itself provides the food source for those primary invaders able to penetrate the seed coat and mature within the grain kernel. Secondary invaders require broken or damaged grain kernels or other grain remnants to assure their survival. Harvesting methods and the subsequent handling prior to storage generally provide enough damaged grain to support a buildup of secondary invaders.

Since the food sources is provided, environmental conditions become all the more critical. Temperature, humidity and moisture content of the grain are the principal environmental conditions affecting stored grain insect buildup. Nature has provided stored grain insects with a short egg to adult development period, a high reproductive rate, and long adult lifespan as a means of surviving the rigorous environment of stored grain and other products. Temperatures in the 65-75 degrees F. range are required for the optimum development of most stored grain insects. While some species may be more cold hardy than others, temperatures below 50 degrees F. will greatly slow feeding activity. Seven days at temperatures in the 15-20 degrees F. range will kill most stored grain insects. Cold winter temperatures in northern growing areas are sufficient to kill or retard most stored grain insects if the low temperatures extend throughout the grain mass.

Moisture is equally critical. Harvesting grain too wet (in excess of 12%) provides an excellent environment for the development of stored grain insects as well as storage molds. Water requirements of stored grain insects are fulfilled primarily from the grain itself. When moisture content of the grain is low (below 10%) the insects must obtain water by breaking down the various grain components or by utilizing their own energy reserves. Either method reduces insect survival. The moisture content of stored grain is usually more than adequate for insect development. However, even reductions in moisture content of one half to one percent can significantly retard insect buildup. Understanding the affects of temperature and moisture on stored grain insect development and properly applying this knowledge will form the basis of a sound pest management program and will insure high quality stored grain.

B. Basic Storage Requirements

Successful management of stored grain insects is dependent upon (1) the selection of proper storage facilities, (2) exercising stringent sanitation practices before and during grain storage, and (3) the timely detection and treatment of insect buildup. Storage facilities may be of many designs. Three broad categories of grain storage structures are:

1. Upright (vertical) storage - Height greater than length or width. Example: silo bins in elevator facilities, butler bins, etc. Bins usually circular or rectangular in cross section;

2. Flat (horizontal) storage - Either length or width greater than height. Example: temporary storage such as railway cars or trailer trucks;

3. Farm-type storage - may be either metal silo type bins, wooden rectangular bins. Often wooden, small and loosely constructed.

The shape and size of a storage facility is important not only from the standpoint of storage capacity but also are critical if the facility should require chemical fumigation. Storage facilities may be constructed of steel, concrete, or wood. They may include elaborate ventilation systems, heaters or driers. Regardless of the size, shape or style, a good grain storage facility should:

1. Hold the grain securely, preventing leaks or spills;

2. Prevent rain, snow, or soil moisture from reaching the grain;

3. Exclude rodents, birds, poultry, etc., from the grain;

4. Protect the grain from fire, theft, or other damage;

5. Allow for effectively treating the grain mass if necessary;

6. Include access from the top to allow for sampling, inspecting, and ventilation.

Realizing the importance of temperature and moisture content of the stored grain mass, it may be desirable to design the storage facility in order to utlizie one or both of these natural factors for prevention of insect buildup. Grain cooled below the activity threshold (50_F.) will result in the starvation and eventual death of stored grain insects. Grain can be cooled during storage by providing adequate ventilation and a good air circulation system that forces outside air through the grain mass. These systems are operated when the outside temperature is

less than that inside the grain mass. Such ventilation removes heat from the grain and exhausts it from the facility. Since increased moisture is undesirable, ventilation systems are generally not operated during periods of rain or fog. It is important that the system be operated long enough to push the incoming cool from completely through the grain mass. Otherwise, some condensation will occur and result in damp areas within the mass. Air temperatures about 10_F. less than the grain mass temperature are ideal for forced grain cooling. Air flow rates in the neighborhood of 1/10 cubic foot per minute per bushel or less for dry grain are preferred.

In contrast, grain driers force warm air through the grain mass to evaporate excess moisture. This technique will also lower the acceptibility of the grain to stored grain insects by stressing their environment. While the use of cool air ventilation or grain driers may not prevent insect infestation by themselves, when utilized with a good inspection program and prompt treatment of developing insect buildups, they can provide a well rounded management program that will prevent quality losses due to insects.

C. Prevention of Stored Grain Insect Buildup

The first step to maintaining high quality grain in storage is to make every effort to insure that the grain is not placed in an already infested facility. Recent studies have shown that in temperate climates, the great majority of stored grain insect infestations originated in and around the storage facility and not in the field. Stringent sanitation practices are the focal point of a sound preventative program. Sanitation should begin with thorough cleaning of harvesting and transportation equipment. Small residues of grain or grain fragments left in trucks and combines are an excellent place for secondary and primary invaders to survive until a more suitable food source presents itself. A continual sanitation program should be followed around storage facilities. Grain or feed spills should be cleaned up quickly. Feed grain and other organic materials should not be stored near a grain storage facility. Each of these sites provide an excellent habitat for stored grain insect buildup.

Preparation of the storage facility should begin at least four to six weeks prior to filling. Thoroughly clean all old grain fragments and dust from walls, floors, and ceilings being careful to reach into all corners and cracks. An effort should be made at this time to make the facility as air tight as possible in case fumigation treatments are required later. Sealing the structure in this manner will also prevent stored grain insects, rodents and other pests from gaining entrance to the grain.

Once the facility has been cleaned, it is desirable to treat the walls inside and outside with an approved residual chemical insecticide to kill any insects not removed during clean up and

prevent the introduction of other insects prior to filling. Be sure to apply the chemical to all cracks and crevices, doorways etc., where pests may enter. An additional preventative step involves applying an approved insecticide to the grain as it is augered into the facility. In many growing areas, a treatment of this type made properly will prevent the buildup of stored grain insects for about one growing season.

D. Detection of Insect Buildup

The longer grain remains undisturbed in storage, the greater the probability of it becoming infested with one or more of the stored grain insect pests. It is important, therefore, that regular inspection (at least monthly) of the facility be made. Inspections will be useful in monitoring grain temperature and moisture. Since the feeding activity of stored grain insects produces heat and moisture, early detection of these "hot spots" will allow for prompt treatment and reduced damage. When summer temperatures favor rapid insect development, inspections should be conducted more often.

Inspection involves taking grain samples from various points and depths of the grain mass. The following equipment is required to complete an inspection: grain probe, canvas catch sheet for handling grain from the probe, series of screens for sieving the grain, a 10X magnifier or binocular microscope to examine samples for insects, several glass quart jars to hold samples should they need to be submitted to a specialist, and an accurate thermometer for measuring the temperature of the grain mass.

The temperature of the grain is usually a good indicator of storage conditions. Temperature is a guide to those areas within the mass that are suitable for insect development. As the surface and perimeter of the grain mass cool, heat and moisture shift from place to place. Moisture generated in warm areas is shifted to cooler areas resulting in damp spots favoring insect and mold development. As the insects become more active, the temperature increases in these areas. During warm weather, infestations tend to develop at or near the surface of the grain mass. During cold weather, temperature readings will point out the likely spots of infestation.

The inspection should begin by examining all exposed surfaces inside and outside the bin. Be especially observant for signs of pest activity or sites of possible pest entry around door ways, aeration ducts, wall joints and seams. Examine the surface of the grain mass for evidence of webbing, live or dead insects, grain fragments, etc., that might indicate insect activity. Check for water leaks through the roof or around the eaves. Next sample the grain. Since warm weather infestations generally begin near the grain mass surface, sample several locations by inserting the probe vertically to its full length and horizontally by laying the probe on the grain and pushing it an inch or so below the surface to collect the sample. During cold

weather, use the thermometer to detect areas where the temperature is above 65 degrees F. Sample these areas with the probe.

Sift all samples through the sieve to separate insects from grain. Examine the screenings with a hand lens or low power microscope for the presence of insects. Compare what you find with the pictures and descriptions given in CHAPTER I of this manual. Generally, the presence of any adults of the granary or rice weevil, lesser grain borer or Angoumois grain moth, indicates a need for treatment. Since most of the development of these pests occurs within the kernel, if treatment is delayed until the immature stages of these pests are plentiful, the body parts of those killed within the kernel become a major source or insect fragment contamination during grain processing. Treatments should also be made as soon as inspection detects larvae, pupae or adults of secondary invaders such as flat grain beetles, sawtoothed grain beetles, red flour beetles or any of the caterpillar pests in excess of 5 per quart of grain sample.

CHAPTER III

CHEMICAL CONTROL OF STORED GRAIN INSECTS

A. Chemical Classification

Chemicals used for the reduction of stored grain insect infestations may be placed into one of three groups:

1. Residual insecticides - designed primarily for cleanup of storage facilities and prevention of insect buildup on or around bin surfaces;

2. Protective insecticides - to be added as a preventative measure to the grain as it is placed into storage;

3. Fumigants - designed for corrective treatment of infestations in progress.

Residual insecticides: include such products as methoxychlor and malathion. Methoxychlor is a chlorinated hydrocarbon used as a 25%-50% emulsifiable concentrate or wettable powder mixed with water and applies as a spray. Malathion is an organophosphate insecticide used as a 50%-57% emulsifiable concentrate mixed with water and applied as a spray. Residual implies that residues of these chemicals will remain on a surface such as a bin wall for a number of days controlling insects contacting the surface.

Protective insecticides: also called grain protectants. For many years the only product registered for this use was malathion. Currently, malathion and chlorpyrifos-methyl (Reldan) are registered for this use and several others will likely achieve registration in the near future. These products are diluted with water and sprayed on the grain as it is loaded or turned into storage. Treatment in this manner should provide protection from insect buildup for one year or less depending upon climatic conditions and the condition of the grain when placed in storage.

Fumigants: are produced in liquid or solid formulations which become heavier than air gases upon evaporation or exposure to the atmosphere. Because of health and safety concerns most of the liquid fumigants traditionally used in grain fumigation (i.e., carbon disulfide, carbon tetrachloride, ethylene dichloride) have been cancelled for this use. Methyl bromide and chloropicrin are still available for use as grain fumigants. However, only those thoroughly trained in the proper handling and safe use of these products should attempt to use them. The principle solid fumigants available are aluminum and magnesium phosphide. Table 1 presents some technical information on the fumigants plus sites for which they are registered.

TABLE 1

TECHNICAL INFORMATION FOR FUMIGANT ACTIVE INGREDIENTS

Methyl Bromide - LD_{50} - 1 mg/liter AVT - 200 ppm
Nonflammable, Colorless, Odorless, Good Penetrating Ability

Chloropicrin - LD_{50} - 0.8 mg/kg
Do Not Use in Processed Food or Feed. Vapors Highly Toxic To Most Plants. Do Not Fumigate Grain if Moisture Content High; Excessive Dockage or Grain Temperature Below 65 degrees F. - Mixed With Other Active Ingredients To Reduce Hazard And As Warning Agent.

Aluminum phosphide - LD_{50} - 2.8 mg/liter
Do Not Use Below 40 degrees F. Aerate Processed Foods - 48 Hours - Respirator Not Usually Needed But Should Be Readily Available. Breaks Down To Ammonia, CO_2, And a Gray Powder. (Aluminum Hydroxide)

AVAILABLE FUMIGANTS

	Active Ingredient	Trade Name	Common Use
1.	Methyl bromide	Methyl Bromide Meth-O-Gas Brom-O-Gas	Bin, truck, container, boxcar fumigation
2.	Aluminum phosphide	Phostoxin Fumitoxin Quick-Phos	Bin, container, boxcar, truck fumigation
3.	Magnesium Phosphide	Magtoxin	Bins, silos, holding tanks, food and feed processing equipment, conveyers and related equipment
4.	Chloropicrin	Chlor-O-Pic	Grain elevators, warehouses, vaults, space fumigation

B. Treatment Methods

Residual chemicals: Thoroughly clean sprayer and mixing containers before and after each application. Make sure the sprayer is in good working order prior to filling with chemical. Tighten or replace worn or leaky connections that might allow chemical to drip onto hands or clothing.

Dilute residual chemicals per label directions. For example: 1 quart of Methoxychlor 25% E.C. is mixed with 2_ gallons of water. Application instructions usually call for 1 gallon of mixed spray to be applied to 500 square feet of surface. Since application rates are subject to change, consult the product label for specific instructions prior to application. Be sure to get the spray into cracks and crevices where residual insect populations may be surviving. Be sure to use fresh spray mixture to treat bins and equipment. Mix only enough chemical to last through one day of application. Do not use spray mixtures that have been allowed to stand over night.

Grain Protectants: Malathion or Chlorpyrifos-Methyl applied as a grain protectant is also diluted with water per label directions. Application rates generally call for 1-5 gallons of spray mixture applied to every 1000 bushels of grain as it is being turned or augered into storage. Products may be applied with a hand sprayer, compressed air sprayer or motor driven pump sprayers. Another popular application method is to allow the chemical to drip at a controlled rate into the grain stream as it enters the auger. Metering devices for this type application are available commercially. A simple home made applicator can be fashioned from a plastic jug, two brass valves and a length of polyethylene tubing. Figure 3 describes the construction of such an applicator. The upper valve serves as the on-off valve while the lower needle valve is used to meter the flow of the chemical. Calibrate the flow of the chemical to the volume of grain moving through the auger. Use the upper valve to start and stop the application. This method of applying the grain protectant assures good mixing and even coverage of the grain as it is placed into storage.

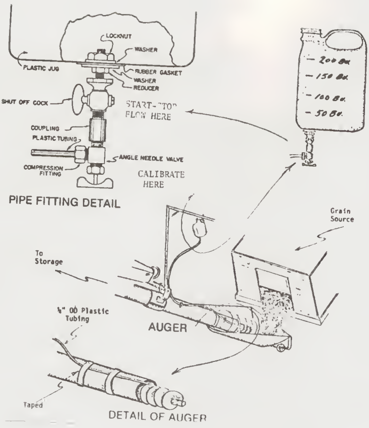


Figure 3: A home made applicator for applying a grain protectant to the grain stream as it is augered into the bin. Adapted from USDA Farmer's Bulletin Number 2269.

Fumigants: are designed to act in a gaseous form to penetrate through the grain mass. They are extremely toxic to all life forms and will control all stages of insects. Fumigants may be applied directly as gases formed as pressurized liquids are released into the atmosphere, as liquids that vaporize when exposed to air, or as solids that produce gases when exposed to air and moisture. Fumigants are generally divided into two classes:

1. "high vapor pressure" - primarily utilized to fumigate "warehoused" commodities or to provide effective penetration of cracks and crevices. Compounds in this group include but are not limited to: methyl bromide, and hydrogen phosphide.

2. "low vapor pressure" compounds which volatilize and diffuse slowly. Primary uses are for treating stored grains that are not gas tight and for soil fumigation.

Fumigation consists of releasing a selected fumigant into a confined airtight space and maintaining a specified concentration of gas within that space for a sufficient time period (1-5 days) to insure adequate control. Although the basic principles of

fumigation sound simple enough, the complex nature of fumigation in practice can not be over emphasized.

Fumigation should not be considered a standard procedure to be followed when storing grain. In fact, there are a number of reasons why fumigation should not be the treatment of choice: 1) fumigants are expensive especially when purchased in small quantities 2) fumigants are extremely toxic and hazardous requiring special use considerations, 3) fumigation is very temporary - there are no residual effects from fumigants. Once the gas has completely dissipated the grain is subject to reinfestation, 4) preparation of the storage facility for fumigation requires additional labor, and 5) fumigation requires at least a two man crew specially trained in fumigation procedures.

The advantages of fumigations include: 1) fumigants are fast acting and if applied correctly they are extremely effective in killing insect pests, 2) since fumigants are gases, they diffuse throughout the grain mass reaching all insect "hot spots" some of which might be missed by other treatment methods. Fumigants will continue to play a key role in the clean-up of infested grain.

C. Fumigation Procedures

Dosage - There are several factors that must be considered before attempting a fumigation. The type of structure, gastightness of the structure, amount of grain in the facility, condition of the grain (i.e. moisture content, percent dockage, compaction, ratio of surface to volume, depth, and temperature both in the grain and outside the facility) will all have an effect on the fumigant dosage and the degree of kill achieved. Table 3 illustrates how some of these factors effect the amount of fumigant required.

TABLE 3

STORAGE CONDITIONS	AMOUNT OF FUMIGANT REQUIRED LESS	MORE
Bin structure	Steel or concrete	Wood
Bin condition	Tight	Loose
Dockage and chaff	Little	Much
Percentage moisture	Low	High
Condition of grain	Normal	Heating
Extent of grain surface to volume	Smaller	Greater
Depth of grain	Deep	Shallow
Compaction of Grain	Loose	Tight

Table 3: Effect of storage conditions on fumigant dosage. Adapted from D.A. Wilbur 1971. In Fundamentals of Applied Entomology, Robert E. Pfadt Ed. MacMillan, New York.

Dosage requirements for grain fumigation are determined first by the quantity of grain in the storage facility. Amounts of fumigant to apply are generally listed per 1000 bushels. Optimum temperatures for fumigation are between 70_ and 90_F. The lower the grain temperature the higher the dosage required as specified on the particular product label. Fumigation of grain below 60_F. is not recommended because insects are generally inactive and will not "take up" the gas as readily. At temperatures of 90_F or above, the fumigant may volatilize so quickly that little will actually penetrate into the grain mass. The type of structure affects dosage requirements primarily based on gas tightness and absorption capacity of the building material. Wooden, unlined bins will require more fumigant because some will escape through cracks and crevices and a small amount will be absorbed into the wood itself.

Application Methods - Application of the fumigant to the grain can be made in several ways. Large bulk storages usually require the use of power sprayers. For storages up to 30,000 bushels, a sprayer that delivers the liquid at the rate of eight to twelve gallons per minute is suitable. Storages exceeding 30,000 bushels should be treated with a hose-pump combination capable of delivering a stream of liquid at least 75 feet at the rate of 100 gallons per minute. Small storages can be treated by pouring the liquid from the top of the bin as the grain is loaded or turned into storage. With this method, twice the recommended amount of fumigant is applied to the first and last 500 bushels.

A pressure sprayer delivering a coarse spray can be used to treat small storages from outside the structure. Bucket, stirrup type or garden type sprayers can be used. A flat coarse spray can be

applied by replacing the nozzle with a piece of 1/4 inch pipe that has been flattened at one end. Application of spray to circular bins should be made to avoid concentrating it in the center of the bin. The outer two or three feet in these type structures contain nearly 60% of the storage.

Fumigation of large elevators has become more sophisticated with the addition of ventilation and aeration systems to the structure design. These types of streams utilize an air stream forced through the grain from the top or pulled down from the bottom. Treatment in these structures is dependent upon the force of gravity to move the fumigant through the grain mass. Forced distribution of the fumigant allows the use of lower dosages, results in quick and uniform distribution of the fumigant and provides a method of thorough aeration of the storage after treatment. Systems are generally single pass or closed recirculation type. The single pass system uses the unmodified aeration system of the structure. The fan is operated long enough to draw the fumigant vapors completely through the grain mass. A closed recirculation system requires a return duct incorporated in the aeration system. Fumigants are introduced at any point in the system and circulated through the grain mass one to several times.

Solid fumigant products like aluminum phosphide can be applied in several ways. Pellets may be applied at the specified dosage by adding them to the grain stream as it is placed into storage. For grain already in storage, probes can be inserted at three to four foot intervals horizontally in both directions. Tablets or pellets are then placed into the probe holes at the specified dosage.

D. Application Procedures

Once the dosage rate and the application methods have been determined, several other considerations must be made as the fumigant is applied. In general, the fumigation procedure calls for: a) the safe introduction of the chemical to the grain, b) sealing the storage facility for the required length of time for adequate circulation and kill, and c) complete aeration of the grain mass following treatment.

1. Introduction of the Chemical: Fumigation should always be carried out in teams of at least two applicators. All team members should be equipped with the proper safety equipment. Prior to introduction of the fumigant the top of the grain surface should be leveled at least 5 inches below the top of the bin. For bin type storage, application should be made from outside the structure. Flat storage may require entering the facility either on the grain surface or on a cat walk directly above. In these situations, application should begin at the point farthest from the door working back towards the exit. A minimum number of

applicators should be inside the structure during the application and there should always be at least one member closely observing the operation from outside the facility to give assistance if needed.

2. Sealing the Treated Structure: Upon completion of fumigant introduction, the structure should be sealed off. All doors, hatches, etc., should be closed tightly and sealed with duct tape or something similar. Placards should be placed on all such openings to warn that the structure is under fumigation. The signs should include the name of the product as well as the date and time of fumigant introduction. Fumigated structures must remain sealed for the length of time specified on the label. Treatment periods may last from 72 hours to 2 weeks depending upon the product used and the type of structure. The grain mass should be left undisturbed during this time period. Boxcars and trailer trucks must remain stationary for at least 48 hours after treatment.

3. Aeration: Once the exposure time has been reached, carefully remove all seals and open enough of the hatches and doors to allow fresh air movement over the grain mass. Do not allow personnel to enter the structure until aeration is complete. There are a number of devices available to detect the presence of any of the fumigant active ingredients. The Fumiscope manufactured by the Robert K. Hassler Co., Altadena, CA, and the Halide detector are particularly useful in monitoring methly bromide fumigations. There are a number of indicators available for detection of hydrogen phophide. However, as a general rule, 24-48 hours should be a sufficient aeration period for most structures.

CHAPTER IV

SAFETY CONSIDERATIONS IN THE TREATMENT OF STORED GRAIN INSECT PESTS

The volatile and poisonous nature of residual insecticides, grain protectants and fumigants renders them extremely hazardous. While malathion and methoxychlor are classified as general use pesticides, fumigants are restricted use pesticides. Persons wishing to apply or supervise the application of restricted use chemicals must become certified by written examination administered by the Montana Department of Agriculture. The examination will test the individuals ability to recognize common pests, read and understand the product label, and apply the product in accordance with label instructions and warnings, recognize the importance of environmental situations that may present themselves during application, and recognize poisoning symptoms and know the procedures to follow in case of a pesticide accident. Contact the Department of Agriculture or the Cooperative Extension Service for further details on applicator certification.

The first step in handling any of the products used for stored grain insect control is to read and understand the product label. The label provides the user with important information concerning safety, rates of the product to be used, pests controlled by the product, approved application sites, mixing and application instructions. Follow label directions to the letter. Of the three groups of chemicals discussed in this manual, fumigants present the greatest safety and health hazard. Since these chemicals quickly volitilize upon exposure to the atmosphere, improper handling of the products can result in inhalation of the toxic vapors resulting in serious injury or death of the applicator or persons nearby. The use of proper safety equipment and common sense will greatly lessen this hazard.

A. Residual and Grain Protectant Chemicals

Common sense will prove to be the best guide in the handling of these chemicals. Start with clean, well maintained equipment. Exercise care in mixing and filling the sprayer. Avoid prolonged contact of the chemical with the skin. Wash all exposed skin with soap and water after application. Should a chemical be accidentally spilled or allowed to come in contact with the eyes or be ingested, follow the first aid instructions printed on the product label. Contact a physician as soon as possible.

B. Fumigants

Liquid fumigants present a hazard in the liquid as well as the gaseous state. In the liquid form, prolonged contact with the skin can cause severe burning and blistering. For this reason it is advisable not to wear gloves and to remove and aerate shoes or boots after fumigation. If liquid grain fumigant contacts the

skin, immediately wash with soap and water. Closely follow first aid instructions on the label should an accident occur. It is advisable to notify a nearby physician or hospital that a fumigation will be conducted, the number of people involved and the chemical that will be used.

Protection from fumigant vapors is of the utmost importance. A properly equipped respirator or gas mask should be worn at all times around a fumigation operation. Canister-type gas masks should be kept in dust free storage when not in use. Prior to beginning a fumigation, a new canister coded to the type of chemical to be used should be attached to the mask. Do not attempt to reuse a canister. Full face masks and canisters should be approved by the Bureau of Mines Safety and Health Administration (MSHA). Since these canisters contain chemicals that absorb the fumigant, the life of the canister varies with the type of fumigant and the concentration. Below are listed the approved color codes for the various canisters:

Fumigant	Color Code
Methy bromide (and other organic vapors)	Black
Aluminum phosphide	Yellow with gray stripe
Carboxide	Black
Sulfuryl Flouride	White with gray stripe
Hydrocyanic acid gas	White with green stripe

There may be times when a full face mask canister type respirator is not satisfactory. As fumigants are atomized or sprayed into closely confined areas, the concentration of the gas may exceed two percent by volume. Such a high concentration will simply overpower a canister-type respirator. Should it be necessary for an applicator to enter a structure with high fumigant concentrations such as in treating a large flat storage, only an air-line or oxygen generating type respirator should be worn. These type respirators have full face masks, but instead of a canister, they utilize supplied or generated oxygen. An air-line respirator is equipped with a hose leading to an air pump located outside the treated structure. One gasoline powered air pump can supply air for several lines. Respirators of this type have some disadvantages: the applicator must drag the air hose around with him, the hose may become entangled or damaged, the engine may fail.

An air pack respirator includes the full face mask and oxygen supply carried in a tank on the applicator's back. As with the air-line type, the applicator is protected from breathing gas but is not protected from skin absorption. Depending upon the size of the tank, the air supply will last up to an hour. The weight of the tank is really the only disadvantage of this type respirator. Instead of a tank, an oxygen breathing apparatus (OBA) has a canister that generates oxygen from the moisture of the applicators breath. The supply is good for about an hour.

Solid fumigants such as aluminum phosphide are somewhat safer to handle and apply. Aluminum phosphide is prepared in tablet or pellet form. These are composed of finely ground aluminum phosphide mixed with ammonium carbonate which gives off ammonia as a warning gas and carbon dioxide. The tablets or pellets begin to decompose upon exposure to the atmosphere, being completely decomposed within 1-4 hours depending upon the formulation. In grain, decomposition may take 3-5 days depending upon the formulation, temperature and moisture. Upon decomposition a fine gray powder, aluminum hydoxide, along with traces of aluminum phosphide remain. The traces of aluminum phosphide rapidly decompose when the grain is moved.

Aluminum phosphide pellets and tablets come in airtight containers. These should be opened only in the open air. The applicator should wear gloves when handling the pellets or tablets and hands should be washed immediately afterward. Since the rate of decomposition of the tablets and pellets is slow it is not usually necessary to wear a gas mask while applying the fumigant. However, a respirator should always be close at hand in case of emergency. Since inhalation of even small amounts of hydrogen phosphide gas can be fatal, it is extremely important to aerate treated structures completely before entering. Detectors are available to monitor the levels of gas remaining in a structure. Respirators should be equipped with a yellow canister with a gray stripe. Refer to the label for first aid information.

In summary, and to re-emphasize the importance of the following proper safety precautions when handling grain protectants and fumigants, carefully observe the following guidelines:

1. ALWAYS carefully read the product label before beginning a fumigation. Pay special attention to the safety precautions, warning, and antidote-first aid information listed. Keep a clean, complete label close at hand in case of emergency.

2. ALWAYS apply liquid fumigants from outside the building or bin.

3. ALWAYS equip yourself with a properly fitting gas mask, air line, or oxygen-generating respirator as required for the type of fumigation you are conducting. Be sure the respirator (canister- type) is outfitted with a canister approved for the fumigant you are using. Replace the canister frequently. A canister used beyond its recommended time period is a hazard and could cause your death.

4. ALWAYS wear clothing that will protect your skin when mixing and applying fumigants. However, do not wear gloves when handling liquid fumigants. Should the chemical be spilled on the skin, immediately remove

contaminated clothing and wash the affected are with soap and water.

5. ALWAYS work in pairs; never fumigate alone.

6. Follow the product label closely as to dosage rates and application procedures. Never fumigate more often or at higher dosages than recommended on the label.

7. Do not disturb treated grain or open newly treated facilities for at least 72 hours after treatment.

8. Never enter a recently treated structure until it has been thoroughly ventilated (at least 24 hours).

9. General first aid: a person suffering from inhalation of a fumigant should be moved to fresh air immediately. Restore breathing if necessary. A victim suffering from ingestion of a fumigant should be revived to consciousness and induced to vomit. In all cases, call a physician immediately.

If you do not have the proper equipment or experience to follow these guidelines, obtain the assistance of a licensed professional fumigator.

CHAPTER V

SEED TREATMENT

A. Introduction

Seeds are subject to many seed and soil-borne pathogens. Seed treatments are used to control disease caused by many of these pathogens. Seed treatment is the application of a pesticide or processing of the seed to reduce, control, or repel disease organisms, insects or other pests which attack seeds or seedlings. Small grains, corn, and most vegetable seeds are often treated to control seed rots, damping off and seedling blight, seedling wilt, root rot, and loose and covered smuts. In Montana, field tests have shown that seed decay and seedling blight organisms rarely cause decreased yields in small grains, therefore, most seed treatments in Montana are for the control of smut fungi.

It is important to correctly identify the disease to be controlled before you can choose an appropriate method of treatment.

B. Important Seed Pathogens

1. Smut Diseases

Smut diseases can cause severe damage and yield reduction in Montana's grain industry. Smut fungi can persist as soil or seed-borne inoculum. To control these fungi, it is necessary to break the life cycle at its most vulnerable stage. The mycelium usually grows along with the growing point of the plant and spores are formed and become obvious only at the time of heading, with sooty masses of spores replacing the seeds at maturity.

Smut fungi that are important in Montana include:

- on wheat - common or stinking bunt (*Tilletia caries* or *T. foetida*), dwarf bunt (*T. controversa*), loose smut (*Ustilago tritici*)
- on barley - covered smut (*Ustilago hordei*) brown loose smut (*U. nada*)
- on oats - loose smut (*Ustilago avenae*) covered smut (*U. kolleri*)
- on rye - bunt (*Tilletia sp*.) - rare

Smut fungi have different modes of infection. The site of infection, seedling, local, or blossom, will influence the type of treatment and control. Both local (seed surface) and seedling infections can be controlled effectively with a protective fungicide. Fungal spores that infect seedlings usually germinate

under the same conditions as the seeds and infect the growing point at this time. However, fungal spores that infect the blossom act like pollen grains and infect during flowering, developing along with the seed. This type of infection can only be treated with a systemic fungicide or hot water treatments that can get inside the seed. Other control measures include use of good quality seed, clean seed with a high level of germination, use of locally adapted varieties, proper fertility, and other good cultural practices.

Common or stinking bunt causes reduction in wheat yields and gives off a foul, fishy odor that makes the wheat unfit for milling. Infected grain can be fed to livestock without injury, however.

Spores are primarily externally seed-borne, as they don't last long in the soil. During threshing, smutted heads are crushed and spores are spread onto healthy heads. Common bunt infects wheat seedlings as they germinate. Temperatures of 50 to 60_F. and moisture cause both spore and seed germination. The smut fungi enter the seedlings and grow in the developing point of the plant, eventually turning the kernels into smut balls. Infected heads may look plumper than healthy heads, but it is hard to determine infection prior to heading. Infected plants are often weaker than healthy and more susceptible to other injury.

Control of common bunt includes use of certified seed and seed treatment. There are several fungicides registered for use in the state that will control common smut of wheat as well as some other seed and soil-borne diseases.

Dwarf bunt is found only on winter wheat. Under favorable environmental conditions, it can cause severe problems in Montana. Infection involves a long, slow process needing heavy snow cover, freezing temperatures, and diminished daylight. Yield loss and prevalence of infection can be directly correlated to these weather conditions. Infected plants tend to be 1/4 to 1/2 as tall as healthy plants. Dry, spined spores are formed in the heads. These smut balls shatter, infecting healthy seed and soil. Smut spores germinate with the seed, infecting the growing point of the plant and growing systemically with the plant. Until recently, the only control recommended for dwarf bunt was use of resistant varieties of winter wheat. Now there is a fungicide registered in the state that aids in control of dwarf bunt when

combined with late seeding. Late seeding is also recommended for control of wheat streak mosaic virus, Cephalosporium stripe and Hessian fly.

Of the barley smuts, brown loose smut is the most important in Montana because it is the most difficult to control. Covered smut and black loose smut infect only the outer layer and are easily controlled by protective fungicides. Covered smuts are covered with a membrane and the remnants of the glume. The membrane is easily broken at maturity and the spores are disseminated by the wind. Loose smuts are only covered by a very thin membrane that immediately ruptures, leaving loose spore masses.

Brown loose smut infects the barley blossom and the mycelium is carried in the embryo of the seed. Diseased and healthy seeds look identical and surface seed treatment will not destroy the infection. To control this disease, it is important for the grower to buy good, clean seed. Use of certified seed and certain systemic seed treatments have helped control losses from this disease.

Seed Decay and Seedling Blight

Disease organisms that can cause seed decay and rot, and seedling blight include Pythium spp., Fusarium spp., Helminthosporium spp., Rhizoctonia spp., and Verticillium spp. Seed rot or decay is the rotting of the seed before germination. Seedling blight or damping off is the soft rot of stem tissues near ground level and water soaking of seedling tissues. Root rot involves water soaking, browning, and sloughing of rootlets.

Dryland foot and root rot can be a problem on wheat, rye, barley, and certain grasses. If seeds are infected, they may fail to germinate or produce, weak, spindly, or stunted plants. Lower leaves turn yellow prematurely and diseased stems turn brown. Badly diseased plants are somewhat dwarfed and die soon after heading out. Heads are often white with poorly-filled, shriveled kernels. The fungus may live for long periods in crop residue, in the soil, or in infected seed. Weather and moisture conditions often determine the destructiveness of this disease because they influence the growth of the fungus as well as the host. More infection occurs when soil temperatures are high (above 60 degrees F.).

The best control measures include use of good, clean seed, fungicidal seed treatment, late sowing, shallow planting, and approved cultural methods (i.e., summer fallowing, rate of seeding, fertilization, weed control, etc.) No varieties are known that are highly resistant.

Strawbreaker foot rot can be a serious problem in localized areas of Montana. It attacks only winter cereals. Symptoms start with pinpoint, water-soaked areas on the outer leaf sheathes. Later, well developed eye-spot lesions that are nearly white and bordered by brown areas appear. At maturity, diseased plants have an excessive number of dead tillers. Near harvest, diseased culms often buckle and fall, marking harvesting difficult. The fungus overwinters on infected stubble and invades susceptible plants in early spring. Entry occurs through direct cell penetration or through stomatal openings.

Serious yield reductions can occur under certain climatic conditions, usually cool, moist springs. Crop rotation is the best available method to prevent serious outbreaks.

Barley net blotch and barley stripe, both caused by Helminthosporium spp. of fungi, are distributed through temperate, humid regions of the world, especially where barley is grown in cooler periods of the year. They are generally of minor importance but can cause foliage reduction.

Symptoms of net blotch include brown reticulate blotches near the leaf blade tip. Young infections show a characteristic netted blotch irregularly distributed. Older infections tend to coalesce the blotches, forming a striping appearance on the leaves. With a net blotch infection, this striping never extends into the sheath.

Barley stripe symptoms become obvious at tillering. First there is a yellow striping of the leaves that will extend down into the sheath area. These areas turn brown and the tissue dies. Usually the stems elongate and often heads fail to emerge or are blighted, twisted, compressed or brown if they do emerge.

The mycelium from net blotch or barley stripe fungi can remain viable for an indefinite period and can be carried from season to season on infected seed and in plant debris. Infection of

net blotch occurs usually in early spring or in the fall in cool, wet weather. Infection of stripe occurs soon after flowering and the mycelium becomes established in the pericarp or embryo. Cool, moist and fertile environmental conditions favor infection and development of both fungi. Free moisture, especially from irrigation, is required for disease development.

The most effective control measures for both diseases include seed treatment, good sanitation methods, crop rotation, and use of resistant varieties.

Potato seed-piece decay organisms can be controlled by use of certain seed treatments. Most tuber rot and storage decay is caused by *Fusarium* spp. of fungi. The fungi overwinter in potato debris or in infected potatoes in storage. These fungi can rot the tubers in the ground or in storage. They also cause wilt of potato plants when infection occurs late in the season. Planting good quality seed, crop rotation, late planting, sanitation, and fungicide seed treatment helps reduce inoculum and infection. Careful handling of potatoes in storage and seed treatment aids in prevention of many storage dry rots.

When bacteria are involved in any type of tuber rot it is important to remember that fungicide seed treatments *will not* control these organisms. Some potato seed piece treatments include a bacteriocide (eg. streptomycin) to control bacteria. You should be familiar with the type of organism you want to control.

3. Rust Diseases

Rust fungi that attack small grains in Montana are not controlled by seed treatments. However, the pathogen causing safflower rust is a seed or soil-borne fungus and can be controlled by seed treatments and crop rotations.

Safflower rust (*Puccinia carthami*) is borne on the surface of the seed and infects the stem of the emerging seedlings. It results in poor stands and reduced vigor of seedlings. Fungicidal seed treatment will control seed-borne safflower ruts. The winter spores of this ruts can survive from one season to the next in the soil but will not survive the second season. Crop rotation will control soil-borne rust spores.

C. Fungicide Treatments

Fungicides are used most often as effective seed treatments. While many seed disease organisms can be controlled by hot water or steam treatment on the seeds, this is a difficult procedure that often results in seed injury and reduced germination.

Seed treatment fungicides are classified as:

Seed disinfectants or systemics eliminate a pathogen which has penetrated into living cells of the seed. Systemic fungicides penetrate the seed or seedling and move systemically in the growing plant or seed embryo, killing or inhibiting the fungi.

Seed disinfestation is the control of a pathogen on the seed surface. Many contact type fungicides will control these organisms.

A seed protectant forms a barrier around seeds and young seedlings protecting them from pathogens in the soil. These fungicides are applied either to the seed itself or to the soil.

Fungicide seed treatments are applied as dusts, slurries, or undiluted liquids. The chemicals can be applied by a commercial applicator or on farm using hand-made dust or liquid applicators. The proper application equipment must be used for each different formulation to achieve complete coverage of the seed and effective disease control.

D. Equipment and Calibration

1. Dust Treaters

Dust treaters weigh out seed as a fungicide power is released from a dust hopper to coat the seed. Calibration is achieved by adjusting the vibrator speed to control fungicide flow. When using a commercial dust treater a preliminary test should be made to be sure the correct amount of fungicide is being applied to the seed. To do this a given weight of seed is run through the treater and a measuring cup is used to catch the powder as it comes off the vibrator. The powder is weighed to determine how much is being applied to the seed. Vibrator speed is then adjusted accordingly.

When a fungicide dust is applied as a drill or planter box application, seed should first be weighed and the appropriate amount of fungicide measured out. Half of the seed is put into the drill box, half of the fungicide added, and mixed thoroughly. Then the remainder of the seed and fungicide should be added

and, again, mixed thoroughly. Complete coverage is important for effective disease control.

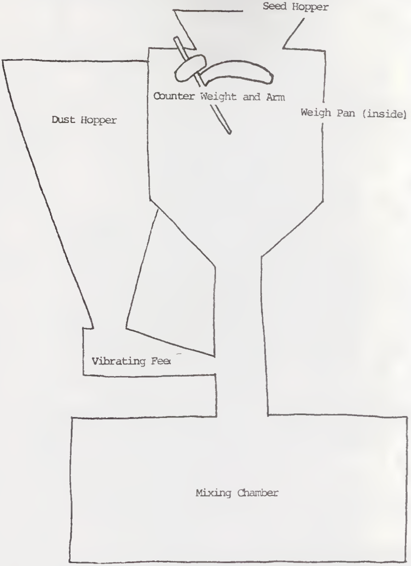


Figure 1. Dust Treater

2. Slurry Seed Treaters

The slurry seed treater keeps a suspension of wettable powder in water and meters a fixed amount onto a given weight of seed. Agitation of the fungicide mixture is important for adequate coverage and control. A seed gate controls seed flow into the dump pan while the fungicide is metered through a slurry cup to the seed. The amount of material applied is controlled by the slurry concentration and the size of the slurry cup used. An auger type agitator mixes and moves the treated seed. Auger speed is important because slower speeds give more uniform fungicide distribution. It is important to remember that the fungicide powder can settle out. If the treater is idle for a period of

time the sediment in the bottom of the slurry cups should be cleaned out.

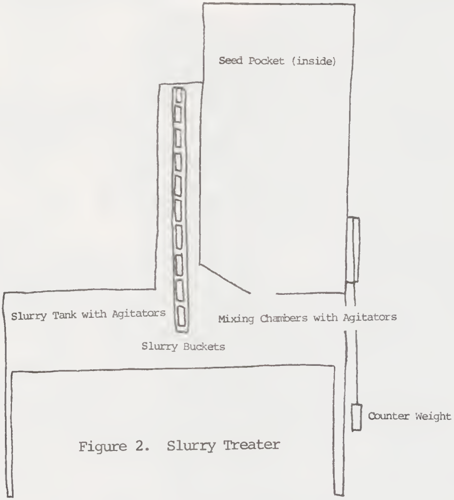


Figure 2. Slurry Treater

3. <u>Direct Treaters</u>

Direct treaters are designed to apply undiluted liquid treatments. The amount of liquid applied per volume of seed is much less than with slurry applicators. These treaters (including both Mist-O-Matic and Panogen) were designed for use with somewhat volatile fungicides that do not require complete, uniform coverage for effective control. Mercury compounds work well in these treaters as they are more volatile than some of the newer fungicides. Mercury products are no longer manufactured and replacement products are not as volatile. Complete coverage is required for good control with newer seed treatment materials.

Modification for direct treaters include the addition of dual tanks that permit simultaneous addition of a

fungicide and an insecticide, and adaptations for the application of slurries.

The metering device in direct treaters is similar to that of the slurry treater. It is synchronized with the treatment cup and seed dump. They differ from slurry treaters in having an adjustable dump pan counter weight to adjust the weight of the seed dump. There are some differences between Panogen and Mist-O-Matic direct treaters also.

The Panogen seed treater (Figure 3) delivers the seed to a hopper scale for accurate measurement. The fungicide is pumped up from the barrel into a reservoir. A small treatment cup, operating off the seed dump pan and out of the reservoir, meters one cup of treatment with each dump of the seed pan. Fungicide flows through a tube to the head of a revolving drum mixing chamber. It flows in with the seed from the dumping pan and is mixed onto the seed as the seed is tumbled in the drum. Liquid overflow from the reservoir is returned to the barrel by a hose. Correct treatment rate is obtained by using the correct size of treatment cup and adjusting the seed dump weight.

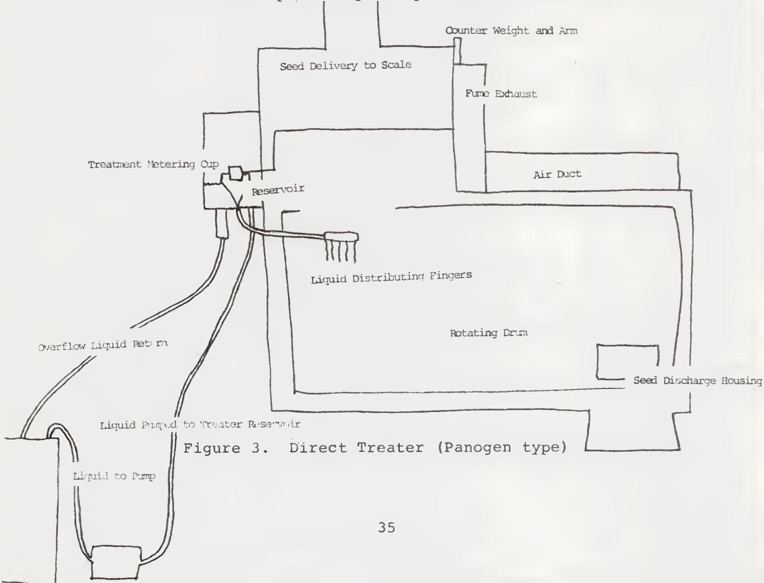


Figure 3. Direct Treater (Panogen type)

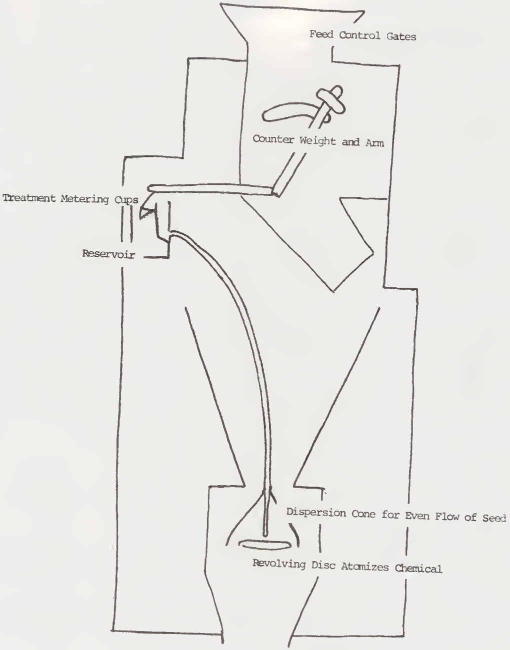


Figure 4. Direct Treater (Mist-O-Matic type)

The Mist-O-Matic treater (Figure 4) applies the treatment as a mist, directly onto the seed. The metering operation uses treatment cups and a seed dump like that found on the Panogen treater. After metering, the fungicide flows to a rapidly revolving, fluted disc mounted under a seed spreading cone. The disc breaks drops of the treatment into a fine mist and sprays it outward to coat seed falling over the cone. It is important to have a continuous flow of seed over the cone between seed dumps to ensure adequate coverage of all seeds. Correct treatment rate is obtained through selection of treatment cup size and proper adjustment of the dump weight.

4. Calibration of Slurry and Direct Seed Treaters

a. Determine how much liquid will dump onto the seed from the metering cup or bucket each time the weighted seed pan trips. This is determined by the size of cup you have on the treater.

b. Run seed slowly into the treater until the weighted seed pan dumps into the treater. Shut off the feed to the treater immediately. Weight the amount of seed dumped into the treater. Record the setting of the weight on the weight balance arm.

c. Determine the number of dumps per bushel by dividing the weight per dump into the bushel weight of your seed.

d. Determine how much of the liquid or slurry you are applying per bushel seed. To do this, multiply the amount of chemical the metering cup dumps into the seed by the number of dumps per bushel. Since most metering cup capacities are measured in cc while chemical recommendations are in ounces per bushel, divide the result by 29.57 to give the liquid ounces per bushel applied.

e. To determine the correct amount of powdered chemical to add to one gallon of water for slurry mixture, divide 128 by the number of ounces of mixture applied per bushel, and multiply the result by the ounces of the chemical you want to apply to one bushel.

f. Mathematical calibration is only a starting point. To ensure that the proper amount of chemical is being applied to the seed the following methods should be used as checks.

Method 1 - Catch the chemical; simply pull the chemical hose from the seed treating chamber and catch a minimum of 10 trips in a measuring cup. If you had 20cc cups you should have caught 200cc of chemical. If not, make the necessary adjustments.

Method 2 -Treated seed comparison; compare the amount of chemical used to the amount of seed treated. This is the most accurate method. i.e. assume a use of 5 gallons of chemical which could treat 70 bushels per gallon. Thus 350 bushels should

have been treated, if not the necessary adjustments.

SPECIAL NOTE: Calibration may be adjusted by:

1. Changing or adjusting chemical cups.
2. Changing the counterweight position upward or downward.
3. Changing the water dilution ratio of the chemical.

Important Calculations for Calibrating Liquid Seed Treaters

$$\text{dumps per bushel} = \frac{\text{bushel weight of the seed}}{\text{weight per dump}}$$

$$\text{ounces of liquid applied per bushel} = \frac{\text{meter capacity (cc)}}{29.57 \text{ cc}} \text{ X number of dumps per bushel}$$

$$\text{ounces of slurry add to one gallon of water} = \frac{128 \text{ oz per gal}}{\text{oz applied per bushel}} \text{ X}$$

oz chemical desired per bushel

Example Problems - Assume 1 bushel = 60 pounds

1. You want to apply 2 oz. of seed treatment chemical per bushel of wheat. You have an 8 pound seed dump. What size chemical cup should you use?

$$\frac{60}{8} = 7.5 \text{ dumps per bushel}$$

$$2 \text{ oz/bu} = \frac{\text{Cup size (cc)}}{29.57} \text{ X } 7.5 \text{ dumps/bu}$$

$$29.57 \text{ X } \frac{2}{7.5} = \text{cup size (cc)} = 7.8 \text{ cup size}$$

2. You want to apply 3 oz. of seed treatment chemical per bushel and you have 15 cc cups on your treater. What dump weight do you need?

$$3 \text{ oz/bu} = \frac{15 \text{ cc}}{29.57 \text{ cc}} \text{ X dumps/bu}$$

$$\text{dumps per bu} = 3 \text{ X } \frac{29.57}{15}$$

$$\text{dumps per bu} = 5.914$$

$$\frac{60\ \text{lb/bu}}{x\ \text{lb/dump}} = 5.914$$

$$x\ \text{lb/dump} = \frac{60}{5.914} = 10.145\ \text{lb/dump}$$

E. Safe Use of Seed Treatment Materials

READ AND FOLLOW ALL LABEL DIRECTIONS WHEN USING SEED TREATMENTS. Correct application rates are important - undertreatment will not control the pest and overtreatment may injure the seed and reduce germination.

ALL SEED SHOULD BE GOOD QUALITY AND CLEANED PRIOR TO TREATMENT. If treated seed must be held over for a season it should be stored in a dry, well-ventilated area away from food and feed. A germination test should be run on all holdover seed.

ALWAYS TREAT SEED IN A WELL-VENTILATED PLACE OR OUTDOORS. When treating or handling seed, avoid inhaling dusts, fumes, vapors, or spray mist. An exhaust system connected to the treater or bagger will remove toxic particles or fumes.

USE PROTECTIVE CLOTHING WHEN HANDLING SEED TREATMENT. An approved respirator or dust mask should be worn when applying dust formulations. Change filters when the fungicide odor becomes apparent or when cartridge becomes clogged. Wear a rubber apron and unlined neoprene rubber gloves when handling all seed treatments. Work with sleeves and pant legs rolled down. Wash clothing after each work day.

WASH THOROUGHLY WITH SOAP AND WATER BEFORE EATING OR SMOKING. Avoid getting seed treatment materials on your skin. All seed treatments are harmful; if swallowed they may irritate the skin or mucous membranes. Follow all recommended first aid found on the label in case of an accident.

DO NOT USE TREATED SEED FOR FEED OR FOOD PURPOSES. All treated seed must be prominently colored to avoid mixture with food or feed. Many pesticides now come from the manufacturer with dye or color already added for convenience. Some formulations need dye added at the time of treatment. Be sure the material you are using dyes the seed to indicate that it should never be used for food, feed, or oil purposes. Treated seed that is bagged or packaged should be prominently labelled.

STORE ALL UNUSED PESTICIDES IN THEIR ORIGINAL CONTAINERS. They should be in a well-labelled, dry, ventilated, and locked storage area out of reach of children, irresponsible people, wild animals, and pest.

SEED TREATERS SHOULD BE IN AN ISOLATED AREA. Do not operate in an area where other personnel or farm commodities used for food, feed, or oil may become contaminated.

SEED TREATERS SHOULD BE THOROUGHLY CLEANED AFTER USE. Some pesticides are corrosive and others may settle out and clog equipment.

DO NOT REUSE PESTICIDE CONTAINERS. They should be mutilated and buried at least 18 inches deep in an isolated area away from water supplies. Treated seed to be disposed should be handled the same as excess or waste pesticide. Treated seeds exposed on the soil surface may be hazardous to birds and wildlife. Discharge contaminated water into a shallow ground pit; do not run it into a stream or public sewer.

FUNGICIDES REGISTERED FOR SEED TREATMENT

Fungicide[1]	Crop Use[2] W	B	O	R	P	SB	SA	SU	For Control of: Seedling Blight (all)	Common Bunt (W)	Loose Smut (W,B)	Cov. Smut (B,O)	Rust (SA)	Seed Decay (P)	Formulations[3]	Method of Application[4]	Comments[5]
captan	X	X	X	X	X	X	X	X	X	0	0	0	0	X	WP, D, L	S, D, PB	cis-N-((Trichloromethyl)thio)-4-cyclohexene-1, 2-dicarboximide
carboxin	X	X	X	0	0	0	0	0	X	X	X	X	0	0	WP, D, L	M, S, D	5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxamide also controls barley stripe
carboxin + thiram	X	X	X	0	0	0	0	0	X	X	X	X	0	0	L	M, S	see above
copper carbonate	X	0	0	0	0	0	0	0	0	X	0	0	0	0	D	D, PB	
imazalil	X	X	0	0	0	0	0	0	X	0	0	0	0	0	L	S	also controls barley scab
mancozeb	X	X	X	X	0	X	X	0	X	X	0	X	X	0	WP	S, D, PB	zinc ion coordinated manganese ethylenebis dithiocarbamate controls foot and root rots
maneb	X	X	X	X	0	0	0	0	X	X	0	X	0	0	WP, D	S, D, PB	manganese ethylenebis dithiocarbamate may be combined with insecticide for wireworm control
PCNB	X	X	X	0	0	0	0	0	X	X	0	X	0	0	WP, D, L	S, D, PB	pentachloronitrobenzene add water for adequate coverage
PCNB + ethazol	X	X	0	0	0	X	X	0	X	X	0	X	X	0	WP, D, L	S, D, PB	PCNB + 5-ethoxy-3-(trichloromethyl)-1,2,4-thiadiazole add water for optimum coverage
TCMTB	X	X	X	X	0	X	X	0	X	X	0	X	X	0	L, D	S, D	2-(Thiocyanomethylthio)benzothiazole
thiabendazole (TBZ)	X	0	0	0	0	0	0	0	0	X	0	0	0	0	L	M, S	2-(4-thiazolyl)benzimidazole aids in control of dwarf bunt in winter wheat; water aids distribution
thiram	X	X	0	X	0	X	X	X	X	X	0	X	X	0	WP, D	S, D, PB	bis(dimethylthiocarbamoyl) disulfide

[1] Check with current label before use; common name of chemical
[2] W=wheat; B=barley; O=oats; R=rye; P=potato; SB=sugar beets; SA=safflower; SU=sunflower
[3] L=liquid or flowable; D=dust; WP=wettable powder
[4] M=mist; S=slurry; D=dust; PB=drill or planter box
[5] includes scientific name